

Measuring skid resistance without contact

2007-2008 progress report

by A Dunford, A Ruff, R Whiteoak

PPR378

PUBLISHED PROJECT REPORT



PUBLISHED PROJECT REPORT PPR378

Measuring skid resistance without contact

2007-2008 progress report

by A Dunford, A Ruff, R Whiteoak (TRL)

Prepared for: Project Record: CONTACTLESS MICROTTEXTURE ASSESSMENT
Client: Transport Research Foundation
(Prof R Kimber)

Copyright Transport Research Laboratory December 2008

This Published Report has been prepared for Transport Research Foundation. Published Project Reports are written primarily for the Client rather than for a general audience and are published with the Client's approval.

The views expressed are those of the authors and not necessarily those of Transport Research Foundation.

	Name	Date Approved
Project Manager	Alan Dunford	16/12/2008
Technical Referee	Alex Wright	16/12/2008

When purchased in hard copy, this publication is printed on paper that is FSC (Forest Stewardship Council) registered and TCF (Totally Chlorine Free) registered.

Contents

Executive summary	2
1 Introduction	3
2 Background and approach	3
3 Images of cores	4
3.1 Core sites	4
3.2 Experimental procedure	4
3.3 Analysis	5
4 Images taken in situ	7
4.1 Test sites	7
4.1.1 Research track	7
4.1.2 Network sites	7
4.1.3 Image collection	8
4.2 Image analysis	9
4.2.1 CMT3 vs average skid resistance	9
4.2.2 Comparing CMT3 and SCRIM trends	9
4.3 Tuning CMT3	11
4.4 Alternative algorithm - shape	13
5 Summary and future work	15
Acknowledgements	15
References	15

Executive summary

A programme of experiments is being undertaken by TRL for the Transport Research Foundation to determine whether detailed imaging of the road surface has potential to be applied to the determination of microtexture and hence to the measurement of skid resistance.

This report describes the most recent stage of research. It has been shown previously that it is possible to derive parameters from the images of stone surfaces which correlate well with friction measured on the surfaces. Whereas work to date has used aggregate samples manufactured in the laboratory and artificial polishing mechanisms, this new research has used images of real-road surfaces.

A new parameter is defined, CMT3, which is based on measurements of the variation in pixel intensities within images, and attempts are made to compare these image derived measurements with measurements of skid resistance. The work was carried out in two stages, firstly using images of cores taken from an experimental surface dressing site and secondly using images taken in-situ at various locations on the road network.

A good relationship is observed in the first stage, using images of cores, but the comparison is not as clear for images of the various road surfaces in the second stage, which may be due to the different textures of the latter surfaces and the differing ways in which the surfaces provide skid resistance. However, where longer continuous sections of road have been imaged, some clear similarities between skid resistance and CMT3 can be observed. Further fine-tuning of the image derived parameter is briefly attempted.

The work has shown that there are still limitations to this technique when a widely varying collection of surfaces are considered, but where it has been possible to make comparisons between continuous measurements of skid resistance, the method is very promising. It is suggested that future work should continue to utilise images of road surfaces in-situ and further investigate and strengthen the similarity between continuous measurements of skid resistance.

1 Introduction

Routine monitoring of skid resistance is an important component of maintaining road surfaces in a safe and serviceable condition. Skid resistance can be measured by various types of equipment, all of which drag a rubber tyre along the nearside wheel path of the wetted road surface measuring the force generated. A contactless method of quantifying the road surface skid resistance has the potential to avoid many of the disadvantages of these systems such as their limited coverage, the logistics of wetting the road in a controlled way and a dependence on speed.

A programme of experiments is being undertaken by TRL for the Transport Research Foundation to determine whether detailed imaging of the road surface has potential to be applied to the determination of microtexture and then to the measurement of skid resistance. The ultimate objective of this work is to develop a method suitable for implementation on a traffic-speed survey vehicle. The work reported in this document is part of the Transport Research Foundation's ongoing research programme. All rights to the intellectual property of this work remain with the Transport Research Foundation.

2 Background and approach

It has been shown that it is possible to calculate parameters from images of surfaces that can be compared to the friction measured. The parameters typically use the assumption that that pixel intensity is a good surrogate for texture such that if the surface is smooth, then pixel intensity will not vary greatly, and the parameter can be designed to reflect this, e.g. by yielding a low number. Conversely, a rough surface will have high variation in pixel intensity, and correspondingly high parameter values.

The previous stage of this work (Dunford (2008)) used images of aggregate samples prepared in the laboratory and artificially polished using laboratory equipment. Parameters, CMT2 and CMT2A, were calculated from the images and were found to correlate moderately well with the skid resistance measured on the samples. The parameters evaluate localised intensity variation along lines of pixels in the image.

Following the work in the previous stage, it was recommended that samples of real-road surfaces should be used instead of laboratory prepared ones, and comparison should be made against measurements of skid resistance made using devices used for routine measurement (i.e. SCRIM). The work described in this report compares image-derived parameters with SCRIM measurements made on road surfaces. The parameter used for the majority of the work, CMT3, is similar to those developed in the previous stage, but due to an increased number of images, more software automation has been used so the parameter has been updated accordingly.

The work was carried out in two stages:

- Using images of cores taken from an experimental road site.
- Using images of road surfaces photographed in situ.

The cores used in the first stage were taken from a length of road with a variety of surface dressings. This allowed the image collection and analysis techniques to be trialled, still on actual road surfaces, before using in-service roads.

In the second stage, in order to progress towards a full scale skid resistance monitoring system, images were taken of road surfaces in situ. A large number of images were collected, first on the TRL research track and then at a number of pre-selected sites on in-service roads.

3 Images of cores

3.1 Core sites

Cores were taken from a site laid in 1999 as part of a project to investigate the ability of laboratory measurements on aggregate samples to predict the in-service skid resistance of road surfacings. Seven different aggregate types were used in surface dressings on the site. Skid resistance was measured on the site, in the nearside wheelpath of lane 1, using SCRIM in February 2004 and September 2004 and cores were taken at approximately the same times. The cores were collected in the nearside wheel path from 15 locations. The cores have been stored in cold, dark, conditions to prevent degradation since removal. Table 3.1 shows details of the sections and the SCRIM measurements in 2004.

Table 3.1 Details of cored trial sections

Section Label	SCRIM Coefficient 2004		Aggregate type	Nominal PSV	Aggregate size
	February	September			
a	0.50	0.48	Granite	55	14
b	0.57	0.55	Gritstone	65	14
c	0.61	0.61	Gritstone	65	10
d	0.51	0.50	Granite	56	14
e	0.54	0.52	Granite	56	10
f	0.52	0.50	Basalt	57	10
g	0.48	0.46	Basalt	57	14
h	0.47	0.45	Granite	55	14
i	0.51	0.49	Granite	55	10
j	0.65	0.68	Dolerite	71	10
k	0.59	0.60	Dolerite	71	14
l	0.53	0.56	BF Slag	56	14
m	0.53	0.55	BF Slag	56	10
n	0.55	0.58	Steel Slag	65	10
p	0.48	0.48	Steel Slag	65	14

3.2 Experimental procedure

Photographs were taken of each core with each photograph covering a width of approximately 50mm. Therefore, two images were created, A and B, for each 150mm diameter core. Example images are shown in Figure 3.1 below.

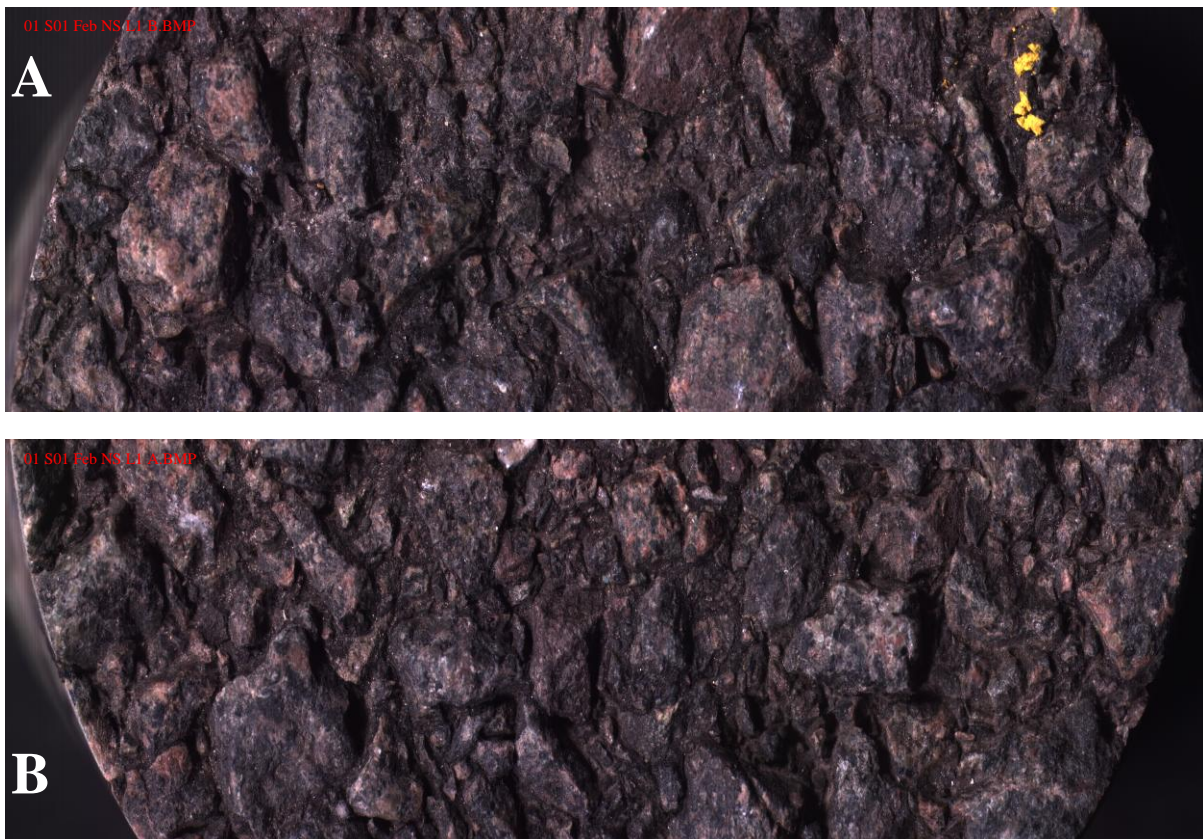


Figure 3.1 Example images, A and B, of core from A31

The images were masked using the procedure developed in the previous stage of this project (Dunford, 2008) with bespoke software (dark areas are isolated and removed – turned to white to be ignored during processing. Details can be found in PPR315). The masked image corresponding to image B in Figure 3.1 is shown in Figure 3.2. Then, data files were created for each image with information about pixel intensity that could be used for analysis.

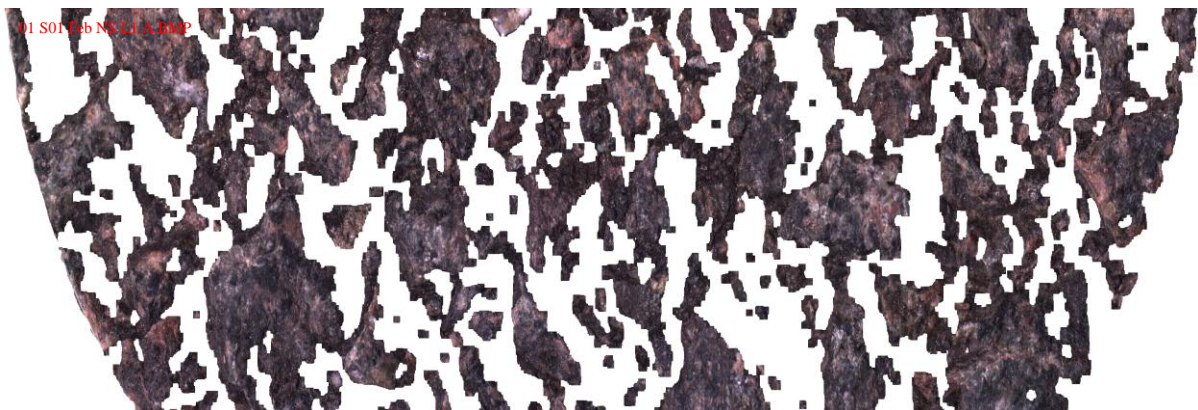


Figure 3.2 Example image after masking

3.3 Analysis

The average parameter value, "CMT3", for images from each core is plotted against the SCRIM coefficient obtained from the SCRIM surveys carried out on the site in Figure 3.3. The rank of the calculated CMT3 values is also plotted against the rank of SCRIM measurements in Figure 3.4. There are two clouds of points, and a trend line is plotted separately for each showing the weak positive correlation. The larger cloud to the top

left of Figure 3.3 and Figure 3.4 consists of data from cores taken from sections surfaced with basalt, granite, steel slag and blast furnace slag, whereas the second cloud to the bottom right consists primarily of data from cores taken from lengths surfaced with dolerite and gritstone. On inspection of the images, the aggregates particles appear darker for the dolerite and gritstone cores than those from the remaining surfaces. The appearance of two clouds of data may be connected to the range of intensity values observed within each image, affecting the CMT3 parameter e.g. a lower intensity range (darker image) may lead, artificially, to a lower measurement of variation in pixel intensity.

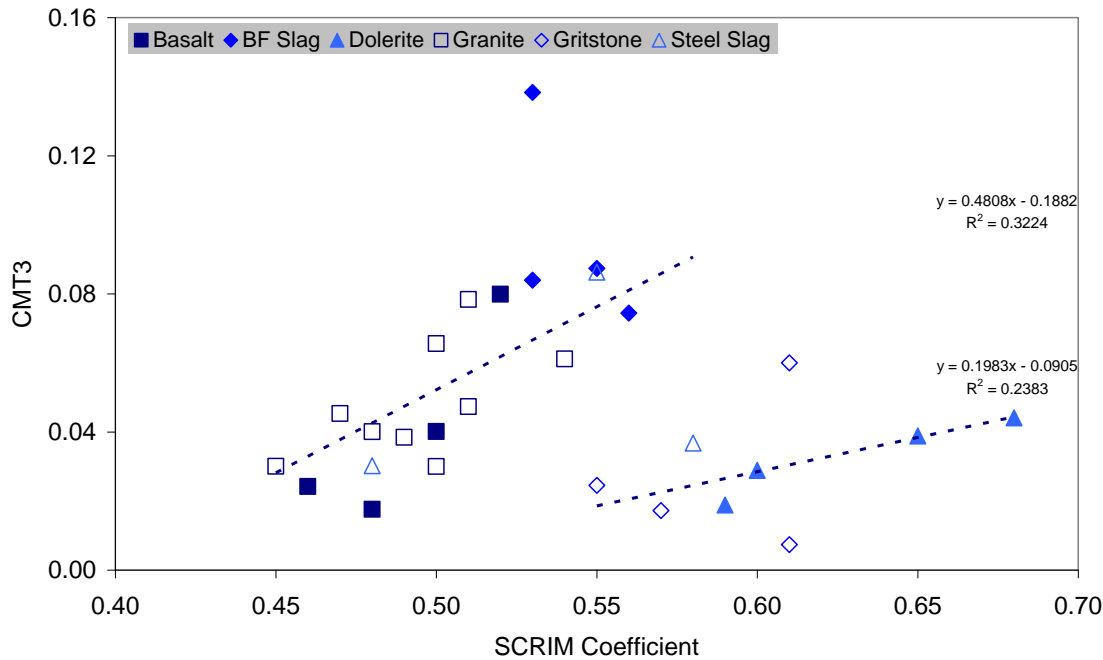


Figure 3.3 Pixel intensity statistical value against SCRIM coefficient for cores from A31

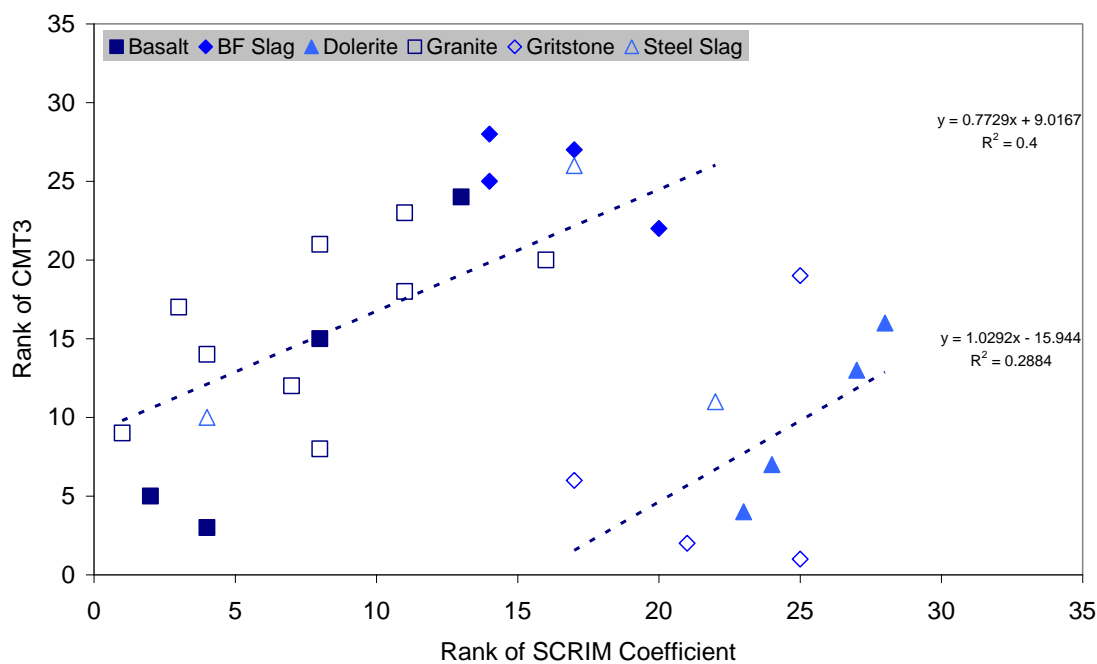


Figure 3.4 Rank of pixel intensity statistical value against rank of SCRIM coefficient for cores from A31

4 Images taken in situ

4.1 Test sites

4.1.1 Research track

The TRL research track provides a safe environment to trial image capture on road surfaces due to the absence of traffic. Additionally, the track has several different types of surface with a range of skidding resistance. Therefore, 5 locations were selected on the track to collect image data. However, because of the absence of traffic, the track does not provide a fully realistic representation of in service roads. The skid resistance on all the surfaces is quite high, with the exception of an artificial surface made using epoxy resin. The average SCRIM coefficients for the locations selected on the track are shown in Table 4.2.

4.1.2 Network sites

Bracknell Forest Council supplied SCRIM survey data and maintenance schedules for roads within the authority. An extract from the surface treatment schedule is shown in Table 4.1 below. The table lists roads within the authority requiring treatment due to a deficiency in the measured skid resistance.

Table 4.1 Extract from Bracknell Forest surface treatments schedule

ROAD	ROAD NAME	ROAD SECTION	Start Chainage (m)	End Chainage (m)	DIRECTION	INVEST. LEVEL (I.L.)	AVERAGE MSSC	DIFFERENCE X 100
D8649	CROWTHORNE RD	85	5	25	NB	0.45	0.27	-0.18
A30	A321 GYRATORY	110	0	29	EB	0.50	0.33	-0.17
A3095	MILL LA RBT	205	167	217	NB	0.50	0.35	-0.15

The road name and number, and the road section was compared with UK pavement management system (UKPMS) databases which give detailed information about the surface condition (texture depth, cracking etc) as well as accurate geographical location information. The geographic information was used to locate the low friction sites on maps of the local area.

Thin surfacing sites with low skid resistance were selected, and site surveys were carried out on foot and/or in a marked car. This enabled checking that the sites were in the condition reported (some inevitably having been resurfaced since preparation of the treatment schedule) and familiarisation with the road layout.

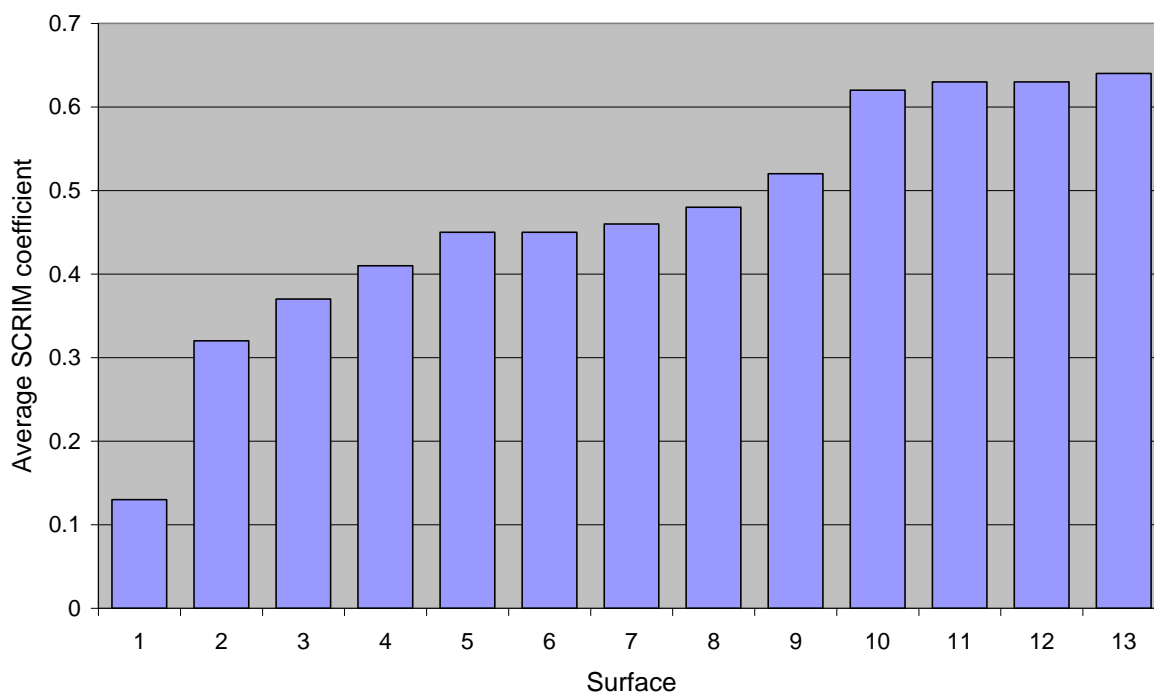
After this second level of filtering, the selected sites were surveyed using the TRL SCRIM to update the skid resistance measurements and to provide data at higher resolution (1m averaging lengths rather than 10m lengths stored in the database).

In addition to these sites, several sites that have been monitored for skid resistance for previous or current TRL projects were included in the list of potential locations for imaging surveys.

Five road sites were finally selected, as shown in Table 4.2 which shows the average skid resistance found at each of the network and research track sites and Figure 4.1 shows this information graphically. It can be seen that a fairly wide range of skid resistance is covered.

Table 4.2 Skid resistance at all imaging sites

Number	Location	Surface type	Average SCRIM coefficient
1	TRL track	Epoxy resin	0.13
2	B4544	Thin surfacing	0.32
3	A420	Thin surfacing	0.37
4	TRL track	Pea gravel	0.41
5	B3348	Thin surfacing	0.45
6	B3034	Thin surfacing	0.45
7	A259_1	Thin surfacing regulating layer	0.46
8	TRL track	Concrete	0.48
9	TRL track	SMA (thin surfacing)	0.52
10	A259_2	Thin surfacing	0.62
11	TRL track	HRA	0.63
12	A259_3	Thin surfacing	0.63
13	A259_4	Thin surfacing	0.64

**Figure 4.1 Skid resistance at all imaging sites**

4.1.3 Image collection

A parallel programme of work carried out by TRL Ltd for the UK Highways Agency aims to develop a system to collect high resolution images of the road surface at traffic-speed. A slow-speed prototype version of this system has been produced that uses a digital colour line scan camera mounted to a trolley, complete with lighting and computer

equipment to collect images. This system has provided the images for all the analyses described in this report.

4.2 Image analysis

4.2.1 CMT3 vs average skid resistance

The first stage of processing the images was to remove areas of the images between the aggregate particles which are not points of contact with the tyre using the masking process described in Section 3.2.

The masked images were then used to calculate the image parameter CMT3, by analysing variation in pixel intensity within each image, in an attempt to find a correlation between the image-derived parameter and skid resistance.

Figure 4.2 shows CMT3 plotted against SCRIM coefficient. The filled symbols represent thin surfacings on the network sites and the open symbols represent surfaces on the track – an additional point is included for surface 6, the B3034 Lovel lane site, highlighting one short section with particularly low skid resistance. Without the points for HRA and concrete from the track (surfaces 8 and 11 respectively, circled), there is a positive correlation but it is very weak.

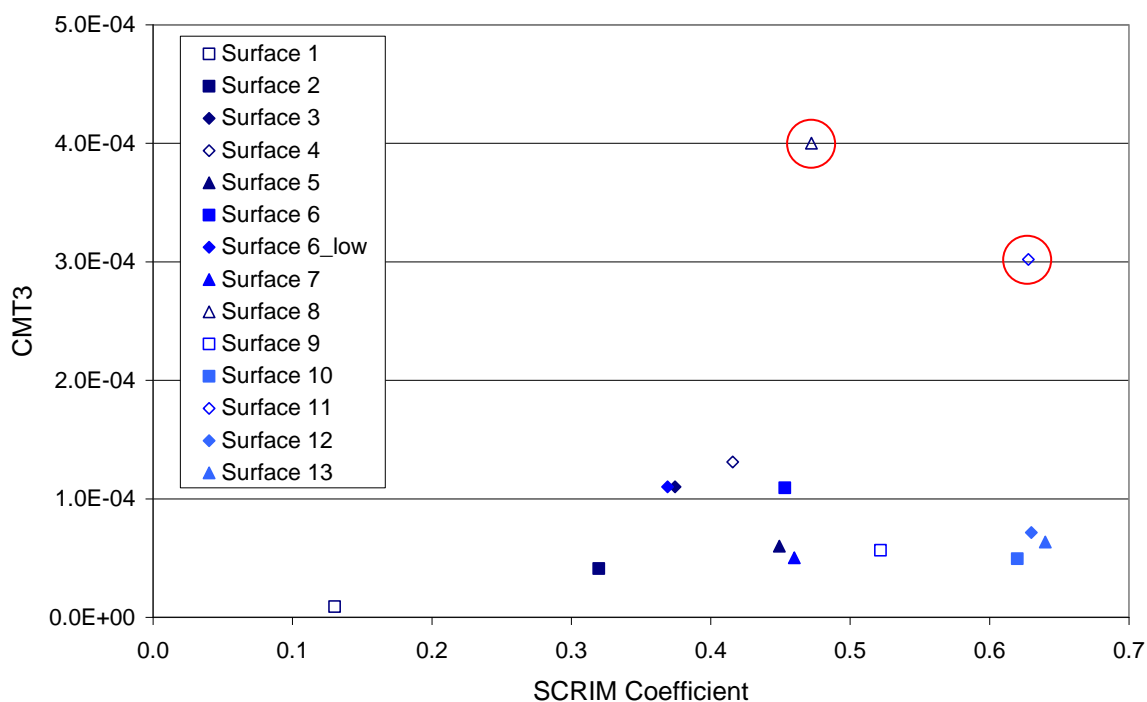


Figure 4.2 CMT3 against SCRIM coefficient for all road/track sites photographed

4.2.2 Comparing CMT3 and SCRIM trends

Although the agreement between SCRIM and CMT3 values was poor when compared over all the surfaces, it was noticed that the trends in CMT3 along the longer sections of road (Lovel lane and Crowthorne road) did bear some similarity to the trends in the SCRIM measurements. Graphs are shown in Figure 4.3 and Figure 4.4 for each case, with SCRIM coefficients in blue and CMT3 in orange. A 4 point moving average is included to smooth the CMT3 data – there being approximately 4 images per metre.

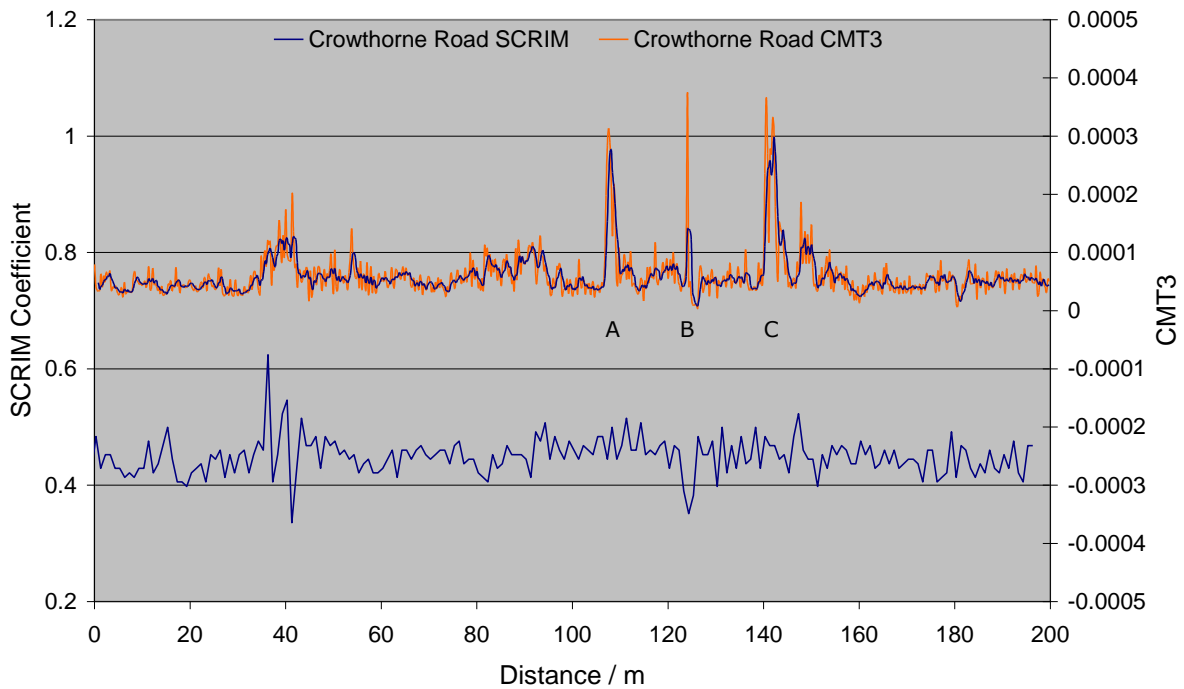


Figure 4.3 Comparison of SCRIM and CMT3 along Crowthorne Road

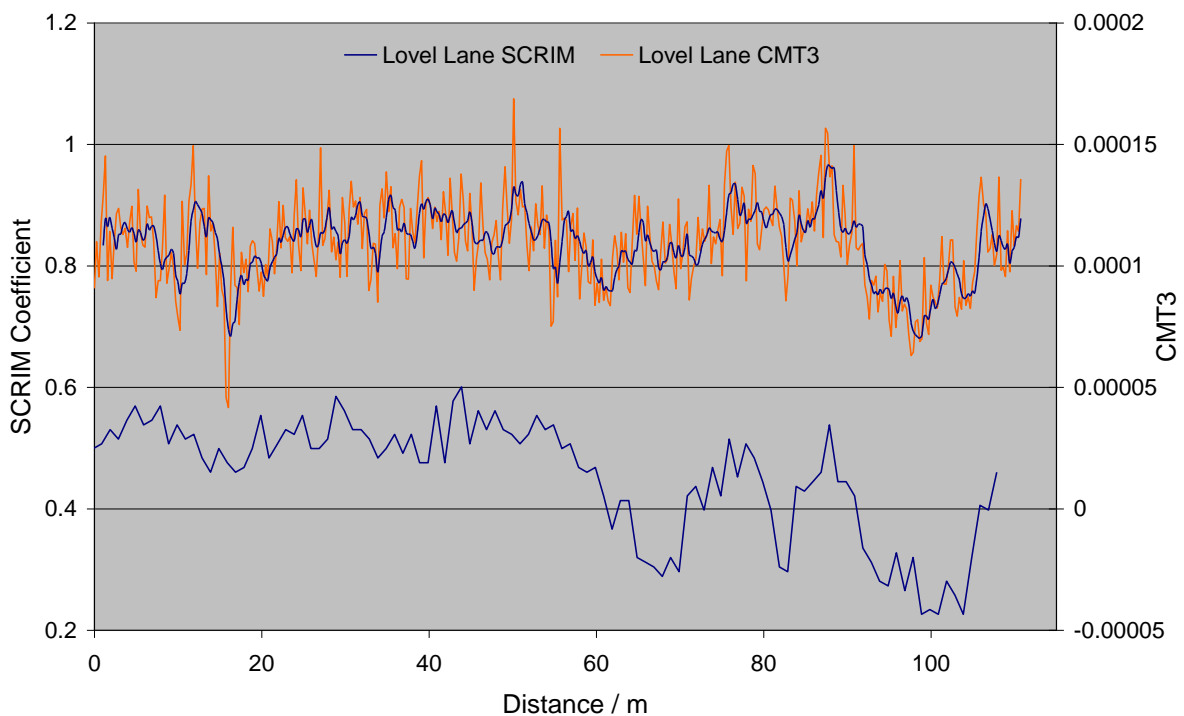


Figure 4.4 Comparison of SCRIM and CMT3 along Level Lane

As can be seen in Figure 4.4, the similarity is considerably better for Level lane which has a larger range of skid resistance than Crowthorne Road (SCRIM coefficients between 0.2 and 0.6 compared with 0.35 and 0.6 on Crowthorne Road). Additionally, there are several points on the Crowthorne Road site where there is little variation in SCRIM coefficient, but large variation in the CMT3 parameter. This occurs most notably at three locations (labelled A, B and C on the graph), and inspection of the images recorded at

these locations revealed that the surface was quite wet. Figure 4.5 shows an extract from one of the wet images. Bright white pixels occur where the surfaces of the stones are wet, and this would lead to an artificially high variation in the pixel intensity. This phenomenon will be important to take into account in future analyses, perhaps by imposing an upper limit for intensity values to be used in calculations, or simply by ensuring images are not collected in wet conditions.



Figure 4.5 Example image from a damp portion of road surface
(brightness altered for printing purposes)

4.3 Tuning CMT3

The software has been developed to allow calculation of the intensity variation parameters (CMT3) within various size areas of the image – the values can then be averaged over the whole image - or along lines of different lengths, and in perpendicular orientations (longitudinally, in the direction of trolley motion, or transversely in the direction of line scanning).

Figure 4.6 shows the CMT3 values calculated from a section of the Lovel Lane site from 50 images, or approximately 12.5 metres. The five different lines were produced using various methods of applying CMT3 to the images: linearly transversely and longitudinally (dark blue and orange solid lines), and square areas of 9, 25 and 49 pixels (broken dark blue, orange and light blue lines respectively).

It can be seen that the same trend is apparent regardless of whether CMT3 is calculated linearly or in areas and is independent of the length or size of the area. When the same values are normalised by dividing each by the average of the series of 50 images, we obtain Figure 4.7. The similarity between the trends holds, with some minor differences, most notably with the 3x3. One important result of this finding is that CMT3 can be calculated in any direction from images of any size, which adds flexibility to the image collection procedures, and may enable use of sampling techniques to increase the speed of image capture.

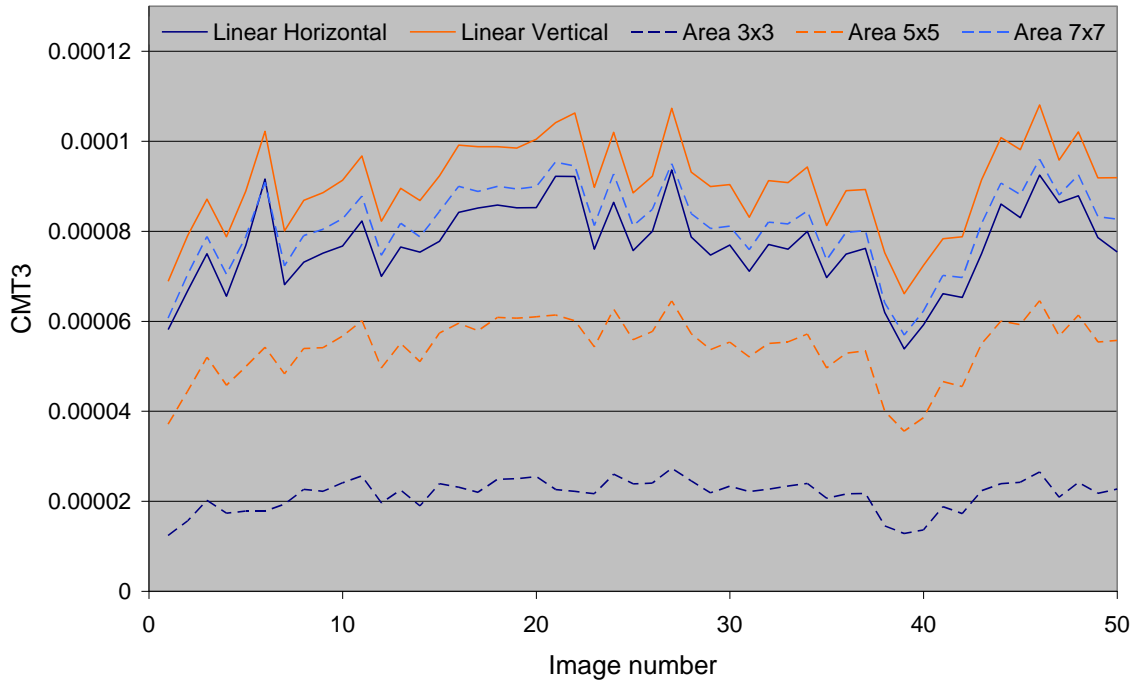


Figure 4.6 Image parameter CMT3 calculated from various averaging sizes for 50 images along a section of the Lovel Lane site.

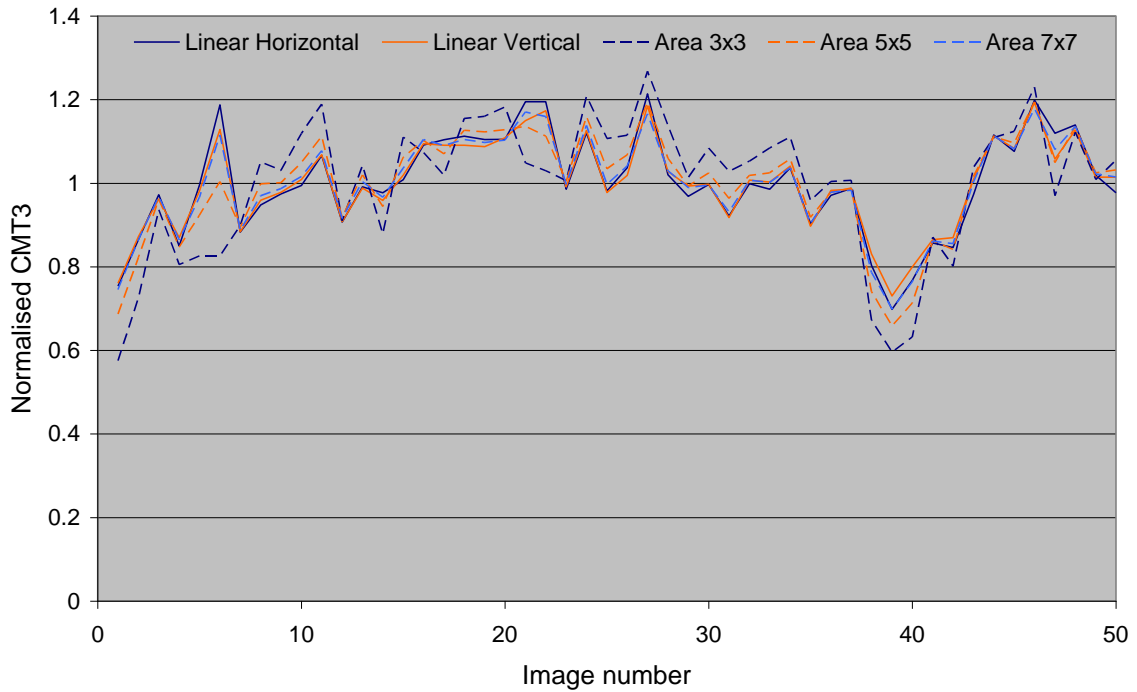


Figure 4.7 Normalised CMT3 for 50 images along a section of the Lovel Lane site.

4.4 Alternative algorithm - shape

To try to establish a stronger correlation between the images and SCRIM readings, a further intensity inspection parameter was developed – CMT4. Previous research (Do, 2005) has obtained a good correlation with skid resistance when the shape of surface asperities and their density was used. CMT4, therefore, attempts to recreate this shape/density characterisation using intensity variation instead of actual height measurements. The parameter is calculated by measuring the gradients in the changes of pixel intensity through the image as well as the individual values.

Figure 4.8 illustrates the three parameters that are used to characterise the shape of surface asperities and their density. The shape is defined by the angle 2α at the summit of “indenters” – the portion of the surface profile between valleys which deforms the tyre when it comes in contact. The density is calculated from the number of indenters per unit length of profile, using the width of the indenter, $2L$, and the third parameter θ defines the relief of the surface, being the angle formed by the segment connecting the summits of two consecutive indenters with the horizontal.

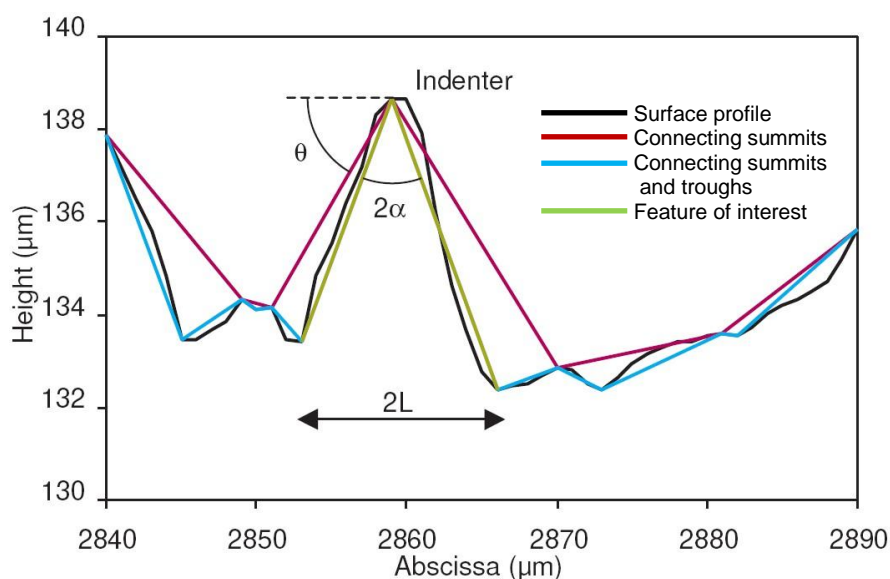


Figure 4.8 Shape measurements made to correlate with friction
(reproduced from Do (2005))

The graph in Figure 4.9 compares the parameter CMT4 with SCRIM on the Lovel lane site. When compared with the graph for CMT3 (Figure 4.4), although on a different scale, the overall shape of CMT4 is nearly identical. However, there is considerably less noise in the CMT4 data (the varying orange line) and the trough at approximately 100m is deeper.

This method of analysing the pixel intensities depends on how the summits, valleys and indenters are defined. It has been suggested anecdotally that only the peaks in the surface above a certain height interact with the tyre. The indenter method may be refined by introducing a cut-off height below which indenters are ignored. Although it is being used as a surrogate for height variation, it is not clear at this stage exactly how the intensity variation from the images relates to the surface profile. However, it may be possible to use a similar filtering method to refine the CMT4 parameter and this will be revisited in future work.

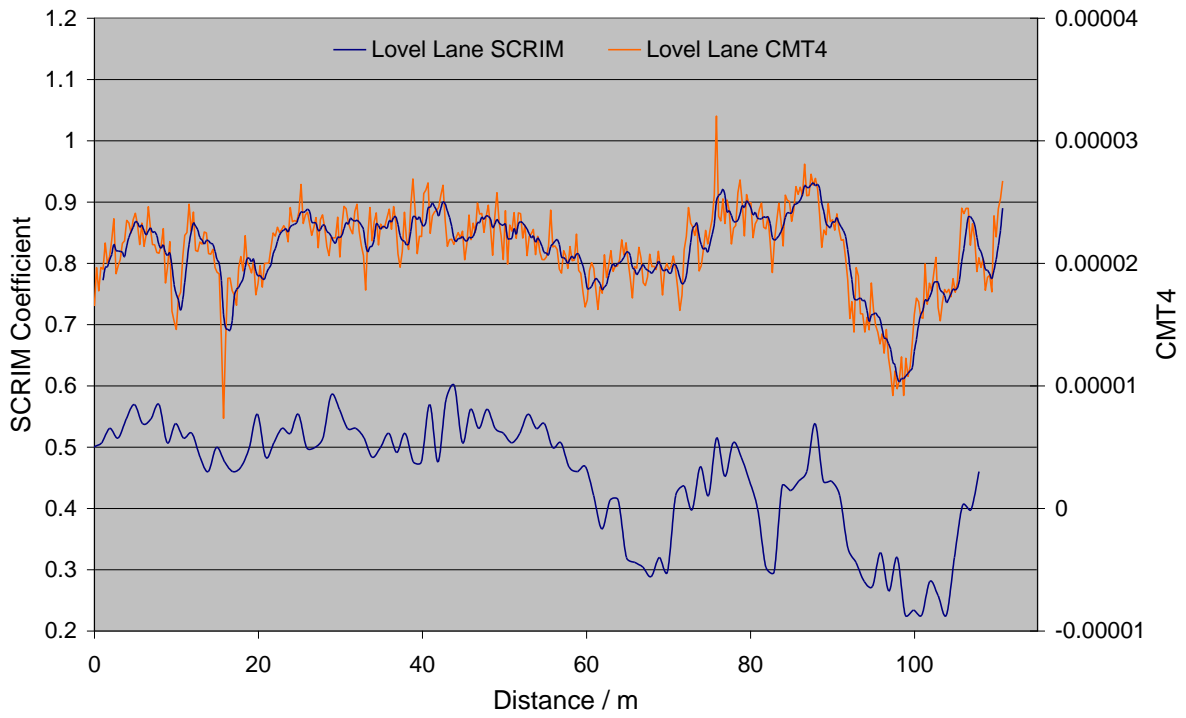


Figure 4.9 Comparison of SCRIM and CMT4 along Level Lane

5 Summary and future work

The research sponsored by the Transport Research Foundation aiming, in the long run, to measure skid resistance without contact using the assessment of microtexture remains ongoing. In the stage described in this report, initial attempts have been made to use measurements on real road surfaces, either as cores from the road, or in-situ at local sites, rather than surfaces manufactured in the laboratory, as used in previous stages.

Cores from an experimental site with surface dressings made from a variety of materials, and having a moderate range of skid resistance (SCRIM coefficients between 0.45 and 0.61) were photographed. It was possible to analyse the images in such a way that the cores could be ranked for skid resistance with some accuracy.

Using images collected in-situ on a variety of surfaces on local roads or on the TRL research track, having a wide range of skid resistance (SCRIM coefficients between 0.13 and 0.64), attempts were made to correlate the parameter CMT3 calculated from the images with the average skid resistance of the section of road. It was found that only a very weak correlation could be achieved.

Although the correlation between average values was poor, visual comparison of the trends in the data showed good agreement between CMT3 and SCRIM.

A limited amount of tuning of the CMT3 parameter was undertaken, and it was found that the parameter was largely invariant to alterations to the area of the image used to calculate the intensity variation. Further development of the algorithms to follow work by Do et al (which in turn followed Forster (1981)) which used the shape of the surface asperities showed very similar results to CMT3 but with slightly less noise.

It is therefore recommended that in future research, more effort should be concentrated on making comparisons between trends in CMT3 and measured skid resistance along the surface, and designing new parameters that take into account the overall shape of the surface (or intensity variation).

Acknowledgements

The work described in this report was carried out in the Safety and Consultancy Group of the Transport Research Laboratory. The authors are grateful to Helen Viner and Alex Wright who carried out the technical review and auditing of this report. The survey work was carried out using the Highways Agency image capture system.

References

Dunford A (2008). Measuring skid resistance without contact; 2006-2007 (PPR315). *Published project report*. Wokingham: TRL Limited.

Minh-Tan Do (2005). Relationship between microtexture and skid resistance (255 pp117-136). *Bullitin Des Laboratoires des Ponts et Chaussees*. LCPC.

Forster (1981). Aggregate microtexture: Profile Measurement and Related Frictional Levels (FHWA/RD-81/107). FHWA.